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Thermal Expansion of Yttria-Stabilized Zirconia

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This paper presents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

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by T. H. NIELSEN AND M. H. LEIPOLD

ZIRCONIUM oxide stabilized with yttrium oxide has many high-temperature applications. This material is of current interest as a susceptor in high-frequency induction-heating furnaces. Since little information is available on zirconia at temperatures above 1500°C in an oxidizing environment, a study was initiated to measure the thermal expansion of this material in air and in a high-oxygen atmosphere.

A mixture of zirconium oxide and 15 wt% yttrium oxide was calcined at 1725°C for 6 hours. The resulting calcine was pulverized and aqueous slip cast into slugs which were fired at 1700°C for 24 hours in an oxidizing atmosphere.* Spectrographic analysis of the fabricated specimens indicated that they contained approximately 1.0 wt% Hf, 0.2 wt% Al, 0.15 wt% Si, and 0.1 wt% Mg. Single-phase cubic structure was indicated by microstructure and X-ray analyses.

The room temperature-to-1000°C expansion measurements were made in an automatic recording dilatometer. Measurements above 1000°C were made in an oxide induction furnace and the change in length of the specimen was measured with telemicroscopes. The equipment and procedures are described in a previous paper by Nielsen and Leipold.[1] In the present tests the oxide induction furnace was modified so that the temperature at the end of the specimen was never more than 10°C from the average specimen temperature. The high-oxygen atmosphere was a mixture of approximately 95 wt% O_2 and 5 wt% N_2.

Table I lists the specimen characteristics. Specimen LA-10 was fired in the oxygen-nitrogen mixture to 2050°C for 1/2 hour before testing. Since both specimens LA-9 and LA-10 sintered during testing, the data were corrected for the shrinkage. The mean coefficient of thermal expansion curves for ZrO_2 + 15 wt% Y_2O_3 are presented in Fig. 1. There was no significant difference in the thermal expansion measured in the two atmospheres.

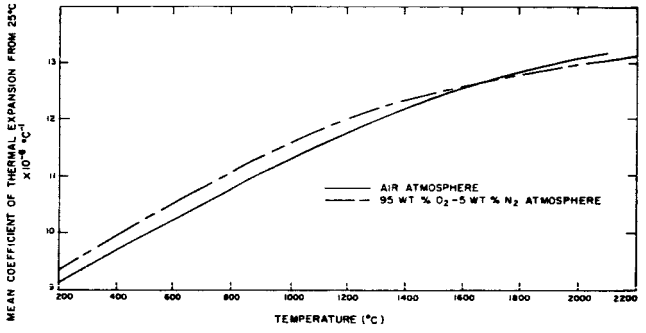

Fig. 1. Mean coefficient of thermal expansion curves for ZrO_2 + 15 wt% Y_2O_3.

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* The specimens were fabricated by the Ceramics Group CMB-6, Los Alamos Scientific Laboratories.

[1] T. H. Nielsen and M. H. Leipold, "Thermal Expansion in Air of Ceramic Oxides to 2200°C," *J. Am. Ceram. Soc.*, **46** [8] 381-87 (1963).

Table I. Specimen Characteristics, ZrO_2 + 15 wt% Y_2O_3

Specimen	Maximum test temp. (°C)	Grain size (μ)	Lattice parameter a_0 (A)	Density (gm/cm³)	Test atm.
LA-9	As fabricated	41 ± 3	5.1377 ± 0.0004	5.48	Air
	2025	67 ± 5	5.1380 ± .0007		Air
	2075	74 ± 11	5.1378 ± .0005	5.60	Air
LA-10	2050	49 ± 6	5.1376 ± .0007	5.44	O_2 + N_2*
	2075	58 ± 8	5.1376 ± .0007		O_2 + N_2
	2200	64 ± 10	5.1370 ± .0005	5.56	O_2 + N_2

* 95 wt% O_2 + 5 wt% N_2.